

Concise report

Evidence for distorted mental representation of the hand in osteoarthritis

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Abstract

Objectives. Some chronic pain states are associated with a distortion of the perceived size or shape of the painful area, and multisensory illusions that disrupt these dimensions can modulate pain in healthy controls and people with painful disorders. Illusory hand resizing has recently been found to relieve pain in hand OA, raising the possibility that the illusion corrects some underlying perceptual disturbance. We evaluated this possibility by measuring perceived hand size in healthy controls and those with painful hand OA before and after illusory hand resizing. The aim was to investigate whether people with painful hand OA have distorted representations of hand size and whether these representations are malleable. We hypothesized that hand OA is associated with a distorted mental representation of the painful hand and that perceived hand size can be modulated via multisensory illusion.

Methods. Twelve volunteers with painful hand OA and 12 healthy age-matched controls performed three tasks (hand stretch, hand shrink and no illusion) in a randomized order then estimated the size of their hand using an adjustable photographic image.

Results. Our hypotheses were supported: under normal conditions, perceived hand size was smaller for the OA group than for healthy controls, consistent with a distorted mental representation of the painful hand. Furthermore, illusory stretching increased perceived hand size in both groups, while illusory shrinking decreased perceived hand size in healthy controls but not in the OA group.

Conclusion. These results suggest that hand OA is associated with a distorted mental representation of the painful hand and are consistent with the idea that the pain relief offered by multisensory illusions may work via normalization of this distortion.

Key words: osteoarthritis, body schema, body matrix, MIRAGE, multisensory illusions, distorted mental representation, body representation, cortical representation.

Introduction

That pain is felt within the confines of our physical selves—that pain is a bodily experience—is widely accepted and usually taken for granted. The ability to accurately localize something within the body or to confine a sensation to the true physical constraints of the body requires an intact body representation (i.e. an accurate mental or

cortical representation of the body). There is a growing body of literature, however, suggesting that the ability to localize pain can be disrupted both experimentally and in clinical pain states (see Moseley *et al.* [1] for a review). Indeed, patients with complex regional pain syndrome (CRPS) often overestimate the size of their painful body part [2] and people with back pain can feel as if their back is missing altogether [3], raising the possibility that the relationship between pain and the veridical physical constraints of the body has broken down.

Attempts have been made to treat pathological pain by targeting the cortical representation of the body part involved, e.g. via tactile discrimination training (see Wand *et al.* [4] and Moseley and Flor [5] for reviews). Interestingly, pain relief with cortical treatment strategies is accompanied by improvements in tactile acuity (i.e. a

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surrogate measure of cortical representation in the primary somatosensory cortex for that painful body part), suggesting that pain relief and cortical representation may be linked [6]. One cortical treatment strategy that appears promising is illusory resizing of the painful body part. Recent work has shown that visually resizing a painful hand modulates the pain and swelling evoked by movement in CRPS patients [7] and the pain evoked by a hot thermode in healthy volunteers [8].

Analgesic benefits of illusory hand resizing have also been found in painful hand OA [9]. Combined with preliminary evidence of impaired performance in tactile acuity and motor imagery tasks in OA patients [10, 11], this finding raises the possibility that the pain of OA may relate to a body perception disturbance and that correcting it might bring relief. We were interested in the possibility that illusions that stretch or shrink the hand might correct a disturbance in the perceived size of the painful hand. We hypothesized that people with hand OA have a distorted representation of the size of their painful hand when compared with healthy controls and that perceived hand size can be modulated via multisensory illusions.

Methods

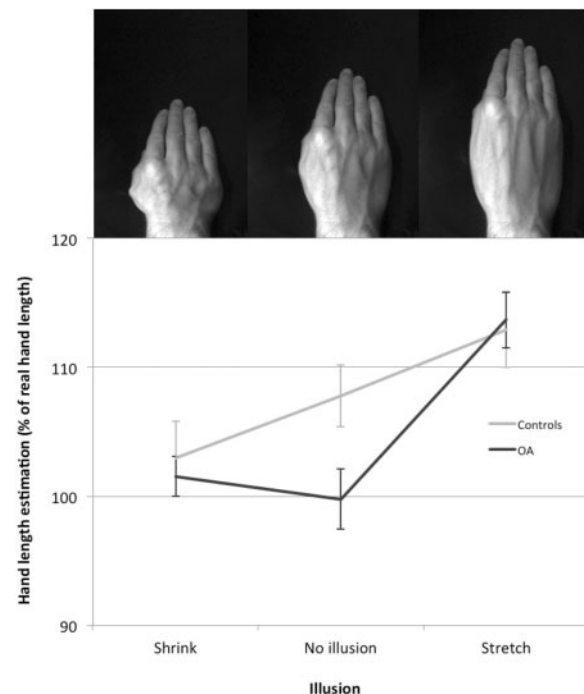
Participants

Twelve people with painful hand OA (4 males) and 12 healthy age-matched controls (6 males) participated in the study. To be included in the OA group, participants were required to have received a clinical diagnosis of OA in the hands at least 12 months earlier. Healthy controls were required to be pain free in the hands and upper limbs (for full details see supplementary material S1, available at *Rheumatology* Online). All participants provided written consent prior to taking part, but were naive as to the purpose of the experiment. The study was conducted in accordance with the Declaration of Helsinki and was approved by the University of Nottingham ethics committee.

Apparatus and procedure

The stretch and shrink illusions were created using a Newport MIRAGE multisensory illusions system [9], which allows participants to view live video images of their hands in the same spatial location and from the same perspective as if directly viewing their hands (see supplementary Fig. S1, available at *Rheumatology* Online). The illusion [9] involved the participant seeing the live video image of their hand being lengthened or shortened (see Fig. 1), while simultaneously seeing and feeling the experimenter gently pulling (for the stretch illusion) or pushing (for the shrink illusion) on their hand. Participants undertook two experimental conditions (stretch and shrink) and a control condition (no illusion) and the order was randomized and counterbalanced across participants. For the OA group, the experimental hand was their most painful hand. For the control group, the experimental hand was their dominant hand.

Fig. 1 Effect of illusion and group on hand length estimates



Example of arthritic hand after being shrunk, stretched and after no illusion. Mean hand length estimates as a function of group (OA, controls) and illusory condition (shrink, no illusion, stretch). Error bars indicate ± 1 s.e.

Hand size estimations were obtained after each condition (while participants kept their experimental hand still inside MIRAGE) using an adaptive staircase procedure. Participants viewed a snapshot image of their hand, which was manipulated in length until participants judged that it looked the right size to be their real hand (see supplementary Fig. S2, available at *Rheumatology* Online). Estimations were recorded as a percentage of real hand size (for full details of experimental procedures and the hand size estimation task see supplementary material S1, available at *Rheumatology* Online).

Statistical analysis

All statistics were performed using SPSS 21.0 (IBM, Armonk, NY, USA). To determine whether people with painful hand OA had a distorted representation of their painful hand, hand size estimations made during the no-illusion condition were compared between the two groups using an independent *t*-test. A 2×3 mixed analysis of variance (ANOVA) with between-factor group (OA, control) and within-factor condition (stretch illusion, shrink illusion, no illusion) was used to determine whether hand size estimations varied between groups and conditions (i.e. if resizing illusions altered perceptions of hand size and if these alterations were specific to each group). If interactions were present, Bonferroni-corrected interaction

contrasts ($\alpha=0.025$) comparing each illusory condition with the no-illusion condition across OA and controls were used to investigate any differences in the effect of the illusions between groups.

Results

The OA group was 53–75 years of age with a mean age of 60.1 years. Controls were 52–67 years of age with a mean age of 58.92 years. All participants completed all conditions, resulting in no missing data. When participants viewed their own hand in the no-illusion condition and then estimated the true size of their hand, hand size estimations (as a percentage of real hand size) were significantly smaller for the OA group [$M=99.80$ (95% CI 94.61, 104.99)] than for the control group [$M=107.81$ (95% CI 102.55, 113.06)], $t(22)=2.39$, $P=0.026$; see Fig. 1]. Further, there was an effect of illusion on hand size estimations, but this effect was specific to group (see Table 1 for percentage change data). That is, there was no main effect of group [$F(1,22)=.964$, $P=0.34$], but there was a main effect of illusion [$F(2,44)=31.56$, $P<.001$] and a significant interaction between illusion and group [$F(2,44)=4.58$, $P=.016$] (see Fig. 1). Interaction contrasts comparing each illusory condition with the no-illusion condition across the OA and control groups revealed a significant difference in the effect of the stretch illusion [$F(1,22)=10.67$, $P=.004$] and the shrink illusion [$F(1,22)=6.42$, $P=.019$], depending on group, such that hand size estimations following no illusion were smaller for the OA group than the control group while hand size estimations following the stretch and shrink illusions were similar between groups (Fig. 1). There seemed to be floor effects in the OA group, with the shrink illusion decreasing hand size estimations for the control group but not for the OA group (Fig. 1), which indicates that hand size estimations for the OA group under normal conditions may be unusually low.

Discussion

We hypothesized that people with hand OA would have a distorted representation of the size of their painful hand when compared with healthy controls and that perceived hand size could be modulated via multisensory illusions. Our hypotheses were supported. Under normal conditions, hand size estimations in people with painful OA of the hand were smaller than those of healthy age-matched controls. Further, illusory stretching increased perceived hand size in both the OA group and the healthy controls (and to a relatively greater extent in the OA group), while shrinking only reduced perceived hand size for the control group (see Table 1 for percentage change data), indicating that OA sufferers may have abnormally small perceptions of their painful hand under normal conditions. As such, one plausible mechanism for the analgesic effect following illusory hand stretching in people with OA is that the illusion experimentally restores a more normal perception of hand size.

TABLE 1 Percentage change scores

Group	Stretch illusion, % change	Shrink illusion, % change
Control	4.80	−4.55
OA	14.26	2.12

Calculated as the percentage change in mean hand size estimation (from no-illusion condition) following stretch and shrink illusions in OA and control groups.

That no overall size reduction was observed following the shrink illusion in the OA group (Fig. 1) is perhaps not surprising, given that it has already been demonstrated that there are limits to embodying an alternative limb that is smaller than one's real hand [12]. It is interesting to note that the OA group in the current study actually showed a slight increase in size estimation after illusory shrinking. This result may help to explain the analgesic effects of both shrinking and stretching found previously [9], although why illusory shrinking should increase perceived hand size is currently unclear. The observation that any illusory change to the body may promote the resetting of normal body representations, as has been implied by the effect of vestibular caloric stimulation in amputees with phantom limb pain [13], clearly requires further investigation in a larger sample.

While hand size estimations in the OA group were, as hypothesized, different from those of healthy controls, the OA group's estimations more closely reflected actual hand size. This finding extends previous research suggesting that implicit mental representation of hand shape is inaccurate in healthy participants [14]. While the findings of the current study differ in the dimensions of inaccuracy in healthy controls, perhaps reflecting differences in the viewing medium and estimation procedure, they clearly corroborate that hand size estimations in healthy people can be inaccurate. That people with OA appear to be more accurate is, in itself, abnormal, and suggests that they may be relying on different mechanisms or body models when estimating the size of their painful hand.

Previous research into other chronic pain conditions suggests that the experience of pain is associated with perceptual and sensorimotor disturbances in the affected body part [1–3, 6]. Combined with the poor correlation between the degree of pain and the extent of physical damage in knee OA [15], and impaired tactile acuity and motor imagery performance [10, 11], the present findings build on the idea of a disrupted cortical body matrix—a dynamic multisensory representation of both the body and the space directly around it [1]. Various psychophysical interventions such as illusory therapies, sensorimotor training and vestibular caloric stimulation have been found to alter the experience of pain in people with persistent pain [6, 7, 9, 13, 16] (see Wand *et al.* [4] and Moseley and Flor [5] for reviews). It is thought that such techniques

might decrease pain by overriding absent or faulty sensory inputs from the painful limb, thus restoring disrupted representations of the painful body part [17], although there are other feasible explanations [4, 5]. As such, the current research may have important clinical implications for the development of new, novel therapies for OA and should be pursued in larger sample sizes.

Previous studies have used visual illusions to alter representations of the size of a body part using methods such as convex and concave mirrors and magnifying and mini-fying lenses [7, 8]. However, the strongest bodily illusions are known to arise from congruent inputs from multiple sensory modalities, and recent research emphasizes the importance of the synchrony with which sensory inputs converge [18]. This would explain why the current method of illusory hand resizing appears so effective—it is able to integrate visual and tactile information in real time and perfect synchrony. That alterations in body perception can be enhanced by congruent multisensory input is not surprising given the multimodal nature of the representation of the body, and builds on previous research showing that tactile discrimination training is enhanced when CRPS patients receive visual information from the body part being touched [19].

In conclusion, the present study adds to the growing body of evidence that multisensory illusions can strongly influence the way we perceive our body. These findings are consistent with the idea that OA pain is associated with disruption of the cortical body matrix. Further, altering a patient's perception of a painful body part may reduce their pain, as has previously been observed for other chronic pain disorders. These findings have implications for the development of new illusory training therapies for treating chronic pain based on the representation of the painful body part.

Rheumatology key messages

- People with hand OA have a distorted mental representation of their painful hand.
- Perceived hand size can be modulated via multisensory illusions of the hand.
- Multisensory stretch illusions can normalize hand size perception in OA.

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Supplementary data

Supplementary data are available at *Rheumatology* Online.

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